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New materials and their uses

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ABOUT THE COVER

New materials—Photomicrograph by P.E. Danielson, Teledyne Wah Chang, Albany, OR, from Carl Zeiss Inc. shows cross section of modified jelly-roll conductor after heat treatment diffuses Sn through copper matrix to form superconducting Nb_3Sn . Articles about other new materials begin on pages 54 and 62.

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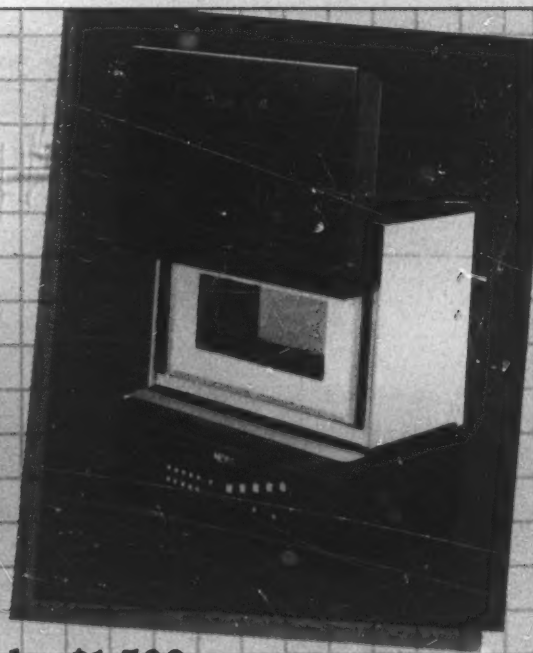
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Soon we all may drive plastic cars

Auto manufacturers and suppliers will share risks and rewards as they substitute composites and reinforced plastics for steel.

Edward M. Hogan
Monkman-Rumsey

THE REPLACEMENT of steel in automobile frames and bodies offers one of the largest opportunities for the application of reinforced plastics and composites. The size of the opportunity is staggering: more than a billion lb/yr for the bodies of standard American sedans alone by the year 2000.

Likewise, the sizes of the incentives and the rewards are staggering. But so are the possible obstacles.

Still, automobile manufacturers are becoming convinced that change is inevitable—indeed, imperative—if the U.S. auto industry is to remain an active competitor in the personal transportation market. These statements are some of the conclusions of a definitive study recently completed by Monkman-Rumsey, a Wilmington, DE, consulting firm that specializes in market studies, technology assessment, and venture management.

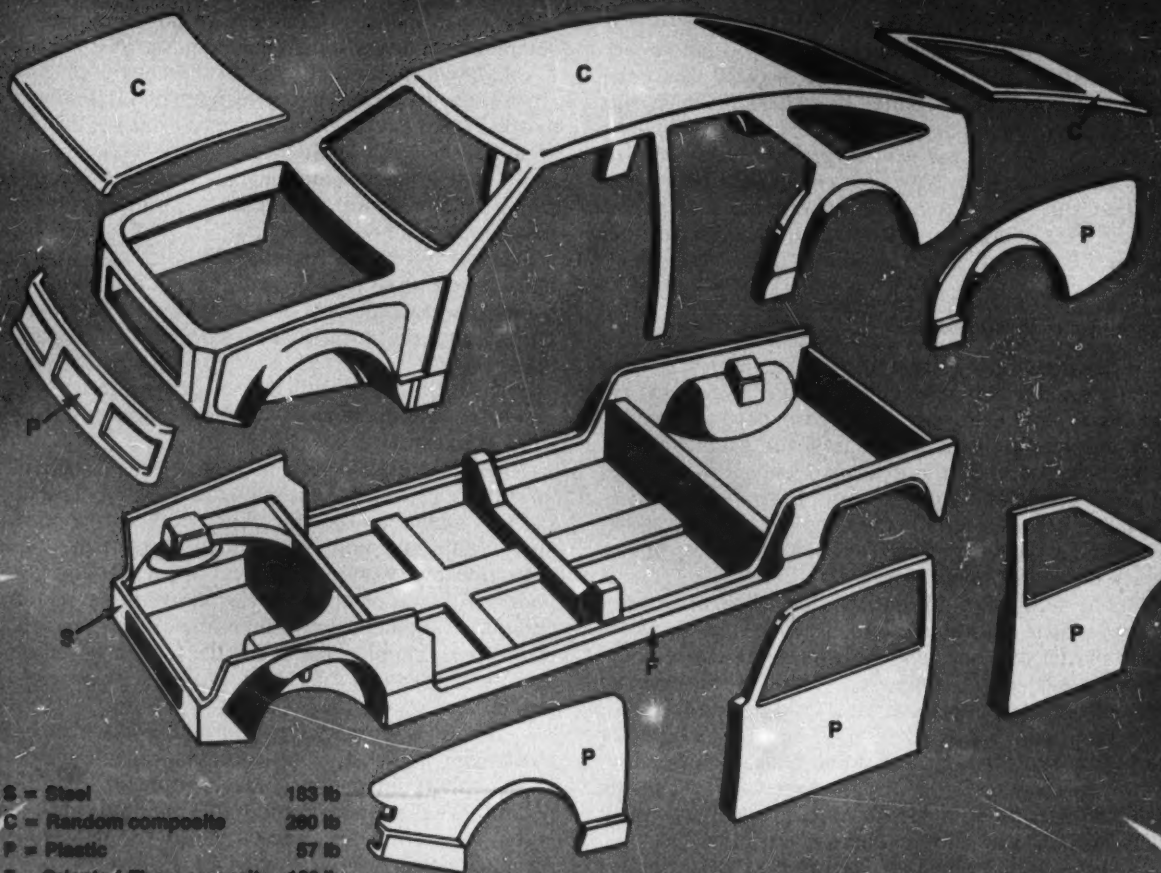
Plastics in cars

The driving forces for these changes are competition and economics. In addition to worldwide pressure for product differentiation and frequent styling changes, U.S. automakers are under severe pressure to reduce costs. The chief threat here, of course, is the likelihood of a \$2,000 to \$3,000 differential in manufacturing cost, compared to automobiles made in Japan.

Because of these pressures, U.S. auto manufacturers are beginning to accept the "plastic car" as the route to the future. The higher costs of plastic materials, compared to the cost of steel, are more than offset by significantly reduced capital investment for tooling, economies in fabrication and assembly, more-efficient



PONTIAC FIERO plastic rear quarter panel resists dents, keeps a "showroom" appearance, and retains physical properties at high and low temperatures (DuPont photo).



S = Steel	183 lb
C = Random composite	290 lb
P = Plastic	57 lb
F = Oriented-fiber composite	100 lb
Total weight, body-in-white (projected concept, Type III)	600 lb

PLASTIC PARTS will replace steel in the structure of an auto "body-in-white," the components of frame and body panels just before painting. Drawing from "The Use of Composites and Plastics for Bodies-in-White in U.S. Passenger Cars, 1990-2000," copyright 1986 Monkman-Rumsey.

deployment of workers, and reduced labor costs.

An added incentive for change is the promise of design freedom, allowing the use of more-complicated and more-complex curves and shapes, along with the relative ease of making rapid design and styling changes.

From the auto owner's point of view, the ability of composites and reinforced plastics to recover from impact minimizes the importance of minor surface damage, such as "dings" and so-called stone bruises. With plastics, these effects will not be as badly disfiguring as they are on a steel-bodied car.

Moreover, plastics do not rust like steel. Since few initial purchasers of automobiles keep their vehicles long enough for freedom from structural rust to have a significant effect on resale value, this advantage may not be particularly important for original-equipment manufacturers (OEMs).

Issues to be resolved

The foremost obstacle to the use of large amounts of plastics in automobile structures is the need for unprecedented cooperation in problem solving and in risk/reward sharing by everyone concerned with auto manufacture. These people include raw-materials pro-

ducers, machine builders, plastics converters, and OEMs.

Critical technical issues that need to be resolved include the following:

- ☐ Establishment of tests and specifications to ensure performance in production and service.
- ☐ Development of tools capable of fabricating large, complex components with forming times of one minute $\pm$ a few seconds.
- ☐ Development of new assembly technology and machinery.
- ☐ Development of systems to recycle and/or dispose of plastic components and cars after they no longer are useful.

These issues will put heavy demands on the R&D capabilities of the entire industry. They also will influence materials selection and the trade-offs involved in determining the "winners" in this major new market for reinforced plastics.

From a technical standpoint, the production of plastic cars is feasible today. This fact has been demonstrated by the limited production of street machines such as the Lotus series and the De Lorean, and by standard-production vehicles—made in progressively larger production runs—from the Corvette, beginning

in the early 1950s to the Fiero in late 1983.

The De Lorean's cosmetic stainless-steel veneer concealed an entire body structure of glass-reinforced polyester. The "space-frame" Fiero design, which separated the visible surface panels from the load-bearing steel cage, opened the way to previously unheard-of versatility in styling. Now, restyling could be accomplished simply by exchanging the reinforced-plastic panels. Retooling for such restyling would cost only about a fifth as much as retooling for a line of steel-skinned cars.

Evolution of plastic autos

In our study we drew upon this experience, then used computer-aided design to examine various material/design combinations to compare performance-to-cost considerations. The results of the study were reviewed with 130 automotive engineers, raw-material suppliers, machinery makers, and component fabricators. The report's authors then applied their own technical and market experience to analyze the data and to reach the report's conclusions.

The study showed that the development of reinforced-plastic automobile bodies probably will evolve from plastic skins for "sporty" cars to the entire body-in-white (structural components and exterior panels) for full-sized family sedans, vans, and pickup trucks.

We used a full-sized "family" sedan as a basis for the study's calculations and predictions since these sedans represent 28% of all passenger cars sold in the U.S. Sedans account for an even greater portion of U.S. automakers' sales revenues and profits.

As a result of our study, we predict that during the next 15 to 20 years the use of plastics and composites in auto bodies will evolve through three design/engineering phases:

□ By 1990, lightly loaded fixed and movable skin panels, requiring Class A surfaces, can be affixed over a load-carrying frame. At the present time, the Fiero is the best example of such an approach.

□ By 1995, manufacture of fixed horizontal composite surfaces that require stiffness to withstand torsion and bending loads in the cab roof and floor, as well as Class A finishes, should be possible. The research version of the Audi 5000S sedan demonstrates this concept today.

□ By about 2000, or perhaps 2005, we will have structural composites for the body pan, the front crash structure, the rear suspension, and the trunk floor, covered by Class A plastic surfaces. No steel will be used, except possibly for the engine-suspension mount. The De Lorean cars were built in this manner.

Solving of problems

A key requirement for making plastic autos successful is parts consolidation. For example, one body design has only 19 components, compared with several hundred parts in steel bodies used today. Assembly can be accomplished in less than 1.5 man-hours of labor, compared with 6 man-hours for the steel designs.

Probably, consolidation will be carried to an even greater extent: Wire ducts, fluid containers, and other details that require time-consuming hand assembly in present designs can be molded into structural parts.

Technically, machinery for processing large plastic

parts at high speeds is feasible now, but continuing development presents some challenging problems. Such development is inherently riskier than developing new engineering materials, and investment capital is harder to obtain. For example, there are no "market-development quantities" for a 5,000-ton press. It is easy to understand that machine builders are reluctant to commit major funds without a guarantee of a market for the products developed.

Other problems include the long development time—often as long as seven years for a single machine—the machine-tool industry's already strained capacity, and the scarcity of some needed technical knowledge and expertise. Few mold shops, for example, have craftsmen skilled enough to produce large molds to close tolerances with the surfaces needed for Class A finishes.

In addition, the lack of industry-wide standards for auto-body panels spotlights the need for standardization, adequate specifications, and testing procedures. Materials suppliers' standard tests, such as heat deflection temperature and Izod impact strength, are poor predictors of actual performance in paint ovens and under impact at low temperatures. Yet, no OEM or materials supplier has taken the lead in developing realistic procedures for characterizing performance of new reinforced plastics.

The development of the required tests will be both challenging and costly, and coordination among materials suppliers and quality control people for parts manufacturers will require considerable time. One problem is that, when they are used on plastic panels, some of the paints that originally were developed for use on metals can cause localized crazing that can reduce the impact strength of the parts to half its original value.

Efforts to develop industry-acceptable specifications and standard test procedures offer solid potential for financial reward in at least two areas:

□ Designers go where data bases exist. There is potential reward in emulating the aerospace industry. In this area, standard methods and data bases available to designers, fabricators, and decision makers have handsomely repaid the materials suppliers' multimillion-dollar development efforts.

□ The company that develops a test accepted by auto designers has the opportunity to define materials standards for that application. Any industry-wide tests will inevitably favor some materials and discriminate

Material projections for standard car bodies
(millions of lb/yr)

Material	1985	1990	1995	2000	2005
Steel	1,714	1,734	1,298	894	520
Random composites	0	159	439	805	743
Plastics (filled and unfilled)	0	67	188	182	183
Oriented-fiber composites	0	0	143	249	286
Total	1,714	1,960	2,068	1,930	1,715
Total composites and plastics	0	226	769	1,036	1,192

against others because of the variety of mechanisms by which composite materials respond to complex stresses inherent in any test that realistically represents performance environments. In fact, the purpose of such tests is to discriminate against materials that cannot perform adequately in a given application.

A full-scale performance data base (excluding paint-over performance) must cover static, fatigue, creep, and impact behavior in realistic stresses at temperatures ranging from -20 F to +150 F, in controlled relative humidity from 5 to 95%, and at impact velocities as high as 55 m/sec.

Materials development and handling

The manufacture of large, complex shapes needed for significant part consolidation at a rate sufficient to feed a 50- to 70-car/hr production line will push processing technology and equipment to the limits of their present capabilities.

For structural parts, compression molding can handle the sizes needed. Still, presses required for major chassis molding will be in the 5,000-ton class. Extensive new investment will be needed here. On a laboratory scale, a 60-sec cycle for auto parts has been demonstrated; the process should be in commercial production by 1990.

Reaction injection molding (RIM) can handle large-sized parts, but only with 2-min. cycle times—4 min. if the parts have to be postcured. Structural RIM and high-speed resin-transfer molding (injecting reactive oligomers around prepositioned glass mats in a sealed mold) are processes that are under extensive development. For these processing techniques, commercial availability dates are uncertain, and it is not known whether the techniques can produce a Class A finish.

Ordinary injection molding has produced Class A finishes on moderate-sized panels (the Fiero quarter panel, for example). At present, however, it is questionable whether the process can be scaled up for the high-speed production of large parts.

At the same time, materials development will be affected by the relative success in resolving other issues. Classes of polymers that can do the job already exist. Any new materials that may be needed probably will come from the development of alloying technology and from interpenetrating-network techniques. Costs at all stages of the development will be important considerations.

Recycling and disposal of plastics

Until recently, neither the automotive industry nor the Federal government has acknowledged the problem of either recycling or disposal of auto bodies containing large amounts of plastics and composites.

To the existing automobile-dismantling and recycling industry, plastics and composites have negative economic value. Any additional reduction in or elimination of economic incentives to collect and recycle worn-out vehicles, or any new regulations about hazardous waste in landfills, could lead to the abandonment of more junked cars—and even more government regulation of manufacturing.

To address the plastics-disposal issue, the Institute of Scrap Iron & Steel (ISIS) has funded two projects.

A recycling study has found that molding of prod-

ucts from scrap is expensive. The only practical products are those that can tolerate a variable mixture of thermoset and thermoplastic materials. The presence of metal scrap and other contaminants rules out processes such as injection molding. To date, products from recycled plastics are confined to fence posts and similar nonprecision, low-value items.

A second project, involving the burning of shredded residue as fuel, is more promising. Shredder residue from early 1970s cars has a fuel value of 5,000 BTU/lb in utility steam boilers, compared with 12,000 to 15,000 BTU/lb for coal. Adding junk tires raises the fuel value to 7,000 to 8,000 BTU/lb. Even at this comparison, the process still complies with existing air-pollution regulations.

The fuel value may change as types of polymers change and as the use of noncombustible fillers increases. Airborne residue from carbon fiber is a possible hazard because of the potential for short-circuiting electrical equipment.

In any case, should the driving force for auto-body recycling change from the present basis in scrap-metal values to energy recovery, the entire character of the recovery/recycling business would change.

The plastics-disposal issue will not become critical until about the turn of the century, when 1989 and 1990 models reach recycling age in significant numbers. There still is time for an industry response, either at the design stage or by the creation of incentives and mechanisms to ensure collection and disposal of the plastic bodies from worn-out cars.

In Detroit, auto designers and manufacturers are beginning to realize that revolutionary changes are needed to achieve major cost savings that can meet foreign competition. One of the most promising approaches is the use of reinforced plastics and composites as structural materials.

As we have noted earlier, overcoming of the many technical and economic obstacles will require extensive cooperation and risk-sharing among auto manufacturers and their suppliers. The rewards will be immense. The R&D community will have to be in the forefront of the effort.

R&D

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